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# UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

|                                          |                 |
|------------------------------------------|-----------------|
| Attorney Docket No.                      |                 |
| First Inventor or Application Identifier | Jing Wang       |
| Title                                    | USB Host System |
| Express Mail Label No.                   | EK441575813US   |

## APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

- ☒ \* Fee Transmittal Form (e.g., PTO/SB/17)  
(Submit an original and a duplicate for fee processing)
- ☒ Specification [Total Pages 22]  
(preferred arrangement set forth below)
  - Descriptive title of the invention
  - Cross References to Related Applications
  - Statement Regarding Fed sponsored R & D
  - Reference to Microfiche Appendix
  - Background of the invention
  - Brief Summary of the invention
  - Brief Description of the Drawings (if filed)
  - Detailed Description
  - Claim(s)
  - Abstract of the Disclosure
- ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 9]
- Oath or Declaration [Total Pages]
  - ☐ Newly executed (original or copy)
  - ☐ Copy from a prior application (37 C.F.R. § 1.63(d))  
(for continuation/divisional with Box 16 completed)
    - ☐ **DELETION OF INVENTOR(S)**  
Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

- ☐ Microfiche Computer Program (Appendix)
- Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
  - ☐ Computer Readable Copy
  - ☐ Paper Copy (identical to computer copy)
  - ☐ Statement verifying identity of above copies

## ACCOMPANYING APPLICATION PARTS

- ☒ Assignment Papers (cover sheet & document(s))
- ☐ 37 C.F.R. § 3.73(b) Statement of Power of Attorney (when there is an assignee)
- ☐ English Translation Document (if applicable)
- ☐ Information Disclosure Statement (IDS)/PTO-1449 [Copies of IDS Citations]
- ☐ Preliminary Amendment
- ☒ Return Receipt Postcard (MPEP 503)  
(Should be specifically itemized)
- ☒ \* Small Entity Statement filed in prior application, Status still proper and desired (PTO/SB/09-12)
- ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
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16. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment:

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**(37 CFR 1.9(f) & 1.27(c))--SMALL BUSINESS CONCERN**

Docket Number (Optional)

Applicant, Patentee, or Identifier: Jing Wang, Ping Liang and Xiaogang Luo

Application or Patent No.: Unknown

Filed or Issued: Herewithin

Title: USB HOST SYSTEM

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- ☐ the owner of the small business concern identified below:  
☐ an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF SMALL BUSINESS CONCERN TransDimension International Corporation

ADDRESS OF SMALL BUSINESS CONCERN 3637 Canyon Crest Drive J100  
Riverside, CA 92507

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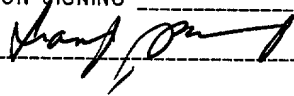
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NAME OF PERSON SIGNING Ping Liang

TITLE OF PERSON IF OTHER THAN OWNER President

ADDRESS OF PERSON SIGNING 14443 Pear Street, Riverside, CA 92507

SIGNATURE



DATE

1/24/2000

**STATEMENT CLAIMING SMALL ENTITY STATUS  
(37 CFR 1.9(f) & 1.27(b))--INDEPENDENT INVENTOR**

Docket Number (Optional)

Applicant, Patentee, or Identifier: Jing Wang, Ping Liang and Xiaogang Luo

Application or Patent No.: Unknown

Filed or Issued: Herewith

Title: USB Host System

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1/24/2000

Xiaogang Luo

NAME OF INVENTOR

Signature of inventor

Date

1/24/2000

**Patent Application of**  
Jing Wang, Ping Liang, and Xiaogang Luo  
**for**

5

**USB Host System**

**Related Applications**

This application claims the benefit under 35 U.S.C. 119(e) of U.S. Provisional Patent  
Application Entitled USB HOST MODULE filed on January 26, 1999, Application No.  
60/117,313.

**Field of the Invention**

The present invention relates to a Universal Serial Bus (USB) host system for embedded  
systems, and more specifically, to a system that has a standard microprocessor interface  
and contains the hardware and software or firmware that implements the USB host  
system including the USB Driver (USBD), Host Controller Driver (HCD), and Host  
Controller (HC).

**Background of the Invention**

The USB is originally developed for personal computers (PCs). The USB also offers  
many advantages for many embedded applications. However, running the USBD and  
HCD on the same CPU or microprocessor or microcontroller in an embedded system  
that runs the application programs often complicates the hardware and software  
designs, and the operating system if there is one, of an embedded system. The CPU, or  
microprocessor or microcontroller in an embedded system that runs the application  
programs will be referred to the Main Processor or Application Processor hereafter. By  
the Main Processor or Application Processor it is understood that it is composed of the  
hardware of a CPU or microprocessor or microcontroller, its I/O interfaces, and the  
associated software or firmware including an operating system when appropriate.

Sometimes, there is not enough system resource on the Main Processor to run the USB Driver and Host Controller Driver. This invention solves these problems with a dedicated processor in the host system, implementing the USBD and HCD, thus, simplifying the hardware and software architecture and the operating system of an embedded system.

A USB host is technically complex, requiring long learning curves. An apparatus that can implement the complex functions of a USB host and presents a simple, high level interface to the Application Processor of an embedded system is desired. The USB host system of this invention implements the USBD, HCD and HC inside the said system and presents a simple high level interface with a microprocessor, thus hiding the difficult details of the USB protocols, USB traffic scheduling, bandwidth management, error handling and recovery, and electrical signaling away from an embedded system developer and from the microprocessor and operating system of the embedded system. This will enable an embedded system developer to integrate an USB host into an embedded system without knowing the technical details of USB, and shorten the time-to-market of his products.

In prior art as shown in the two industry-standard USB host specifications, the "Universal Host Controller Interface (UHCI) Design Guide" Revision 1.1 published by the Intel Corporation, and the "OpenHCI: Open Host Controller Interface Specification for USB," (OHCI) Revision 1.0a, published by Compaq, Microsoft and National Semiconductor, to achieve high transfer rates on USB, the Host Controller requires a bus interface with bus master capability, such as a PCI bus, to interface with the CPU. In many embedded systems, there is no PCI bus. The interface between the USB host system of this invention and a microprocessor or a microcontroller is a non-PCI standard microprocessor bus interface.

The major differences between this invention and prior art USB hosts are given below:

There are USB host related products for embedded systems. ScanLogic, Inc. of Bedford, MA makes a USB Host Controller SL11H. The SL11H is only a Host Controller, it only relates to a small part of in this invention. The SL11H does not have a programmable processor. The USB D and HCD still have to be run on the same

processor as the application programs. VAutomation, Inc. of Nashua, NH offers a synthesizable HDL core of a USB Host Controller with the Host Controller function implemented using software on a RISC processor. This again only relates to a small part of in this invention. It has a programmable processor which only implements the HC. There are other similar products. None of these products offer a complete USB host system with the unique features of this invention, and none of them offer all types of USB command and pipe mechanisms. These products only implement a USB host controller, and USBD and HCD are to be implemented and run on the same processor as the application programs.

The solution to USB host for embedded systems such as those provided by ScanLogic Inc., Vautomation Inc. and similar products have serious disadvantages: Running the USBD and HCD on the Main Processor will take away significant time and memory resources from the application programs. There will be very frequent interrupts (one interrupt for each USB transaction) from the HC to the Main Processor. Since both the application programs and the USB host software all are implemented on the Main Processor, the software structure and management on the Main Processor becomes very complicated.

It is not obvious to use a processor separate from the Main Processor to implement the USBD and HCD because in the USB Specification, USBD and HCD are meant to be part of the drivers of an operating system, and USB Client Software access the USB system through calls to the operating system. In the prior art, USBD, HCD and USB Client Software are implemented on the same Main Processor. The fact that prior art USB Host Controllers that have been developed especially for embedded systems, such as those by ScanLogic Inc. and VAutomation Inc., leave the USBD and HCD to the Main Processor is a strong evidence that using a processor separate from the Main Processor to implement the USBD and HCD is not obvious.

In this invention, the USBD and HCD are implemented using a processor other than

the Main Processor, the Main Processor access the USB system by writing to and reading from a buffer accessible by both the Main Processor and processor implementing the USB system and the Main Processor. The communication is in predetermined formats.

5

### **Brief Summary of the Invention**

The present invention has the following significant advantages over the prior art:

- 10 1. The present invention provides to an embedded systems developer a high-level pipe view of USB host with all four types of pipes, control, isochronous, interrupt and bulk pipes. This shields the embedded system developers from all hardware, system driver and protocol details, including enumeration, attach/detach detection, scheduling, pipe management and error handling on the USB host side. Thus, it  
15 enables an embedded systems developer to design a product containing a full-function USB host and to write USB Client Software without knowing the details of the USB host specification and functions.
2. The present invention reduces complexity on the Main Processor by moving the USB host system to a separate processor. This makes it easier to design an  
20 embedded system and the software for the Main Processor in an embedded system that requires a USB host. The Main Processor's resources can then focus on the application programs. Since all low level USB activities are handled by the host system of the present invention, there will be significantly less interrupts to the Main Processor and significantly less demand on the Main Processor's resources,  
25 making the application programs run more efficiently on the Main Processor.
3. Prior USB host specifications and implementations depend on operating systems calls to access the USB host functions. This invention may provide the user full USB functions using Application Programming Interfaces (APIs), thus, it can be  
30 used to provide USB host functions to an embedded system without an operating system, or with an operating system that does not support USB. In an prior art



USB host implementation that contains the USBD and HCD managed by an operating system supporting USB, the host system of this invention can still be used by intercepting the calls to the USBD and pass the calls to the USBD in the host system of this invention to process the calls.

- 5 4. This invention does not use bus mastering such as the PCI bus for interfacing with the Main Processor in an embedded system. Rather, it uses a standard microprocessor bus interface between the USB host of this invention with the Main Processor. This liberates the USB host system from the PCs and processors and platforms with PCI bus, and enables a full-function USB host to be used in
- 10 any embedded system using any Application Processor. This invention contains a data communication memory (DCM) which can be accessed by both the processor in the USB host system of this invention and the Main Processor. In one embodiment of this invention, the DCM is a dual-port memory. The communication between the Main Processor and the USB host system of this
- 15 invention is done using a plural of predefined record formats. From the Main Processor's point of view, USB transfers now become reading from and writing into the DCM with predefined record formats which can be done by filling templates. This greatly simplifies the task of integrating a USB host in an embedded system.

20

In one embodiment of this invention, there are two groups of software mechanisms to clients: command mechanisms and pipe mechanisms. Command mechanisms allow clients to configure and control USB devices through the device's default pipe. Pipe mechanisms allow USBD client to manage device specific data and control transfers.

25 All four types of USB pipes, default control pipe, interrupt pipe, isochronous pipe and bulk pipe, are supported.

30

A USB pipe is an association between an endpoint on a device and software on the host. Pipes represent the ability to move data between software on the host via a memory buffer and an endpoint on a device. There are two different, mutually

exclusive, pipe communication modes:

- Stream: Data moving through a pipe has no USB defined structure.
- Message: Data moving through a pipe has some USB defined structure.

5 Overall, this invention can provide USB host system to any processor, greatly reduces the manpower and resource requirements for integrating a USB host system into an embedded system and significantly shortens the time-to-market of embedded system products containing full-function USB host. It is an ideal solution to USB host for embedded systems, offering simplicity, easy of use, flexibility, and high performance.

10

#### **Brief Description of the Drawings**

Figure 1 shows the USB host structure and the different components in a USB host system;

15

Figure 2 shows the block diagram of one embodiment of this invention;

Figure 3 shows a typical application of this invention in an embedded system;

20

Figure 4 shows the memory map of the DCM in a typical embodiment of this invention;

Figure 5 shows the format of the Control Pipe Record (CPR) used by one embodiment of this invention for the command mechanism between the Main Processor in the embedded system and the USB host system of this invention;

25

Figure 6 shows the format of the Data Pipe Record (DPR) used by one embodiment of this invention for the bulk and isochronous data transfer pipes and the interrupt pipe;

Figure 7 shows the pre-defined USB commands implemented using the System Command Record (SCR) in one embodiment of this invention;

30

Figure 8 shows the format of the System Command Record (SCR) used by one embodiment of this invention to implement USB system command and pipe command;

- 5      Figure 9 shows the format of the Enumeration and Error Record (EER) used by one embodiment of this invention to notify enumeration and disconnect of USB devices and system errors to the Main Processor in the embedded system.

10      **Detailed Description of the Invention**

Reference will now be made to the drawings wherein like numerals refer to like parts throughout. An embodiment of this invention is a system containing the hardware and firmware implementing all the functions enclosed in rectangle 100 in Figure 1, including the USBD 110, HCD 120, HC 130 and root hub 140. The block diagram of a typical embodiment of this invention is shown in Figure 2. USBD 110 and HCD 120 are run on the processor 210 in the USB host system. The USB host system 200 interfaces an Application Processor through a standard microprocessor bus interface 205. Figure 3 shows a typical application of this invention. The partition of one embodiment of the memory space of the DCM is shown in Figure 400.

20      The USB Diver Interface (USBDI) 160, i.e., the interface between the Main Processor/user Client Software and the USB host system of this invention, consists of exchanging predefined records via the DCM. In one embodiment of this invention, the predefined records include the following:

25      Control Pipe Record (CPR): Client Software initiated control transfer. The format of CPR in one embodiment of this invention is shown in Figure 5.

30      Data Pipe Record (DPR): Client Software initiated isochronous, interrupt or bulk transfer. The format of DPR in one embodiment of this invention is shown in Figure 6.

System Command Record (SCR): Main processor initiated, pre-defined USB system commands. The format of SCR in one embodiment of this invention is shown in Figure 8.

5

Enumeration and Error Record (EER): USB host system initiated, device attach/detach, enumeration and system error report. The format of EER in one embodiment of this invention is shown in Figure 9.

10 To initiate a USB transfer, a client 150 running on the Application Processor 310 writes a request, sometimes referred to as an I/O request packet IRP, as a Record in one of the predefined record format to the DCM 220 of the USB host system 200 through a standard microprocessor bus interface 305. The processor 210 in the USB host system 200 may be notified of the said request using an interrupt to the processor  
15 210. The interrupt may be generated by writing to a special address 425 in the DCM 220. The address of the said request in the DCM 220 may be passed to the processor 210 using predefined addresses 420 and 425 in the DCM 220. The processor 210 then reads the address of the Record from the special address 420 and 425 from the DCM 220. It uses the address of the Record to read the actual Record in area 400 or 410. The  
20 processor 210 then interprets the Record, schedules USB transfers and completes the transfer at the appropriate time via the USB HC 230, the root hub 240 and a USB device 320 when necessary.

The processor 210 returns the status and data, if there is any, of the transfer to the  
25 same area of the Record allocated by the Application Processor 310. The Application Processor 310 may either poll the area of the Record, or be notified by an interrupt from the USB host system 200. The interrupt can be generated by the processor 210 writing to a special address 435 in the DCM 220. The address of the Record in the DCM 220 may be passed to the Application Processor 310 using predefined addresses  
30 430 and 435 in the DCM 220. The Application Processor 310 reads the address of the

Record from the predefined addresses 430 and 435, and finds out which Record the interrupt is about. It then reads the status and data, if there is any, and passes to the appropriate Client software 150. The Client software 150 decides the next step of operation.

5

The USB host system 200 has the function of hot plug and play, and automatically enumerates a USB device 320 when it is connected, and deletes it when it is disconnected. The USB host system 200 uses the EER to report to the Application Processor 310 the addition of a new USB device so that the Application Processor 310 can invoke the appropriate Client software 150 for the USB device 320. The USB host system 200 also uses the EER to report to the Application Processor 310 the deletion of a USB device from the bus so that the Application Processor 310 can disable the corresponding Client software 150 for the removed USB device 320.

15 The USBD 110 and HCD 120 in the USB host system 200 automatically manages the data bandwidth allocation, schedules USB transfers to ensure continuous data stream for isochronous devices and appropriate polling interval for USB interrupt pipes. It maintains the data structure containing the topology of all the devices on the bus, their configurations, interfaces and endpoints. It also maintains the data toggle, error retry and recovery and other USB host functions.

20

The formats of the four Records are presented in detail below.

#### Control Pipe Record (CPR)

25

The CPR implements the control pipe. It has the following format:

ControlPipe:[bmControl, bStatus, wXferCount, bDeviceAddress, bEndpointNumber, bmRequestType, bRequest, wValue, wIndex, wLength, Data]

30

The format of the CPR in the DCM 220 is as shown in Figure 5 for one embodiment of this invention. A Client software 150 initiates a CPR 500. To initiate a control transfer, the Main Processor 310 allocates an area in the DCM 220 for a CPR 500 and writes a CPR 500 in the allocated area. With a single dispatch of a CPR 500 into the allocated area in the DCM 220, three separate stages of a control transfer (setup stage, optionally data stage, and the status stage), as defined in USB Specification, are automatically processed transparently to the user.

The USB host system 200 also uses the CPR 500 to notify the Main Processor 310 of the status of the transfer and any data returned by the device 320. An interrupt to the Main Processor 310 is generated upon completion, or an error condition of a Client Software 150 initiated USB control transfer. Upon receiving the interrupt, the Client Software 150 may read the associated CPR 500 from 430 and 435 in the DCM 220. The Client Software 150 uses the address in 430 and 435 to recognize to which CPR 500 the returned status and data apply. The transfer status, (no error, or an error condition) is given in the *bStatus* field of the Record. The *wXferCount* field will give the actual number of data transferred. Reading 435 clears the interrupt.

If the control transfer requested data from a device 320, the data returned from the device will be in the buffer area designated by the CPR 500. After the control transfer is completed, the Main Processor 310 may release a CPR 500 area in the DCM 220.

#### Data Pipe Record (DPR)

A Client Software 150 initiates a USB data transfer, (isochronous, interrupt and bulk) using a DPR with the following format.

DataPipe: [bmControl, bStatus, wXferCount, bDeviceAddress, bEndpointNumber, wLength, Data]

The format of the DPR 600 in the DCM 220 is as shown in Figure 6 for one embodiment of this invention. The type of the data transfer (interrupt, bulk, and isochronous) and the direction of transfer are implicit and are determined by configuration and descriptor of the endpoint targeted by the transfer. Therefore, the DPR 600 does not specify the type and direction of the data pipe. This avoids inconsistency errors such as attempting to send isochronous data to an endpoint that is supposed to be Bulk IN.

To initiate a data transfer, a Client Software 150 first constructs the desired DPR 600 in DCM 220, and then writes the starting address of the DPR 600 to 420 and 425 in the DCM 220.

An interrupt to the Main Processor 310 is generated upon completion, or an error condition of a Client Software 150 initiated USB data transfer. Upon receiving the interrupt, the Client Software 150 may read the starting address of the associated DPR 600 from 430 and 435 in the DCM 220. This address is the same as the address the Client Software 150 allocated to the DPR 600. The Client Software 150 uses this address to recognize to which DPR 600 the returned status and data apply. The transfer status, (no error, or an error condition) is given in the *bStatus* field of the Record. The *wXferCount* field will give the actual number of data transferred. Reading 435 in DCM 220 clears the interrupt.

If the data transfer requested data from the device, the data returned from the device will be in the buffer area designated by the DPR 600. For bulk and isochronous transfers, once the transfer is completed, the Main Processor 310 may release the DPR 600 area in the DCM.

To establish a USB interrupt pipe, the Client Software must write and dispatch a DPR 600 to UH1000 targeted at the interrupt endpoint. This is equivalent to "enabling" the USB interrupt.

Upon an interrupt condition at a USB device 320, the USB host system 200 generates an interrupt to the Main Processor 310, prompting the user to examine the interrupt DPR 600 with address given in 430 and 435. This address is the same as the address  
5 the Client Software allocated to the interrupt DPR 600. Reading 435 clears the interrupt.

The DPR 600 needs to be issued only once to enable an interrupt pipe. The interrupt can be "disabled" by issuing an "Abort Pipe" command to the interrupt endpoint using  
10 a SCR. Once an interrupt DPR 600 is created in the DCM 220, it should remain there and the area should not be used by other Records unless the Client Software 150 wishes to disable the interrupt from the associated USB device 320.

An important advantage of using the USB host system 200 is to significantly reduce  
15 the number of interrupts to the Main Processor 310. It is important to realize that the data buffer size of a DPR 600 is not the same as the maximum packet size (or buffer) of the designated endpoint. For example, the maximum packet size of a bulk endpoint is 64 bytes, while a Client Software may dispatch a DPR 600 with a data buffer length of 1024 bytes (wLength =1024). The USB host system 200 will automatically break  
20 down the data into the appropriate packet size and transfer to the endpoint. It will only interrupt the Main Processor 310 once when all 1024 bytes are transferred. If the USB host software 110 and 120 are run on the Main Processor 310, the Main Processor 310 will be interrupted at least once for every 64 bytes of data.

25 A Client Software 150 may open multiple buffer areas for data transfer over the same pipe, i.e., set up multiple DPR 600 in the DCM 220 directed to the same endpoint of the same device. This may be critical in maintaining the data rate for isochronous transfers.



### System Command Record (SCR)

The Application Processor 310 may issue pre-defined USB system commands using the SCR with the following format:

5

SysCmd:[bmControl, bStatus, bDeviceAddress, bEndpointNumber]

The pre-defined USB commands are shown in Figure 7. The format of the SCR 800 in the DCM 220 is as shown in Figure 8 for one embodiment of this invention. A SCR 800 is dispatched by first constructing the SCR 800 record in DCM 200, followed by writing its starting address into 420 and 425 in the DCM 220.

10

An interrupt to the Main Processor 310 is generated by the USB host system 200 upon completion (or an error condition) of a USB system command. Upon receiving the interrupt, the Main Processor 310 may read the starting address of the associated SCR 800 from the 430 and 435 in the DCM 220. This address is the same as the address the Client Software allocated to the SCR 800. The Application Processor 310 uses this address to recognize to which SCR 800 the returned status apply. The transfer status, (no error, or an error condition) is given in the *bStatus* field of the Record. Reading the 435 clears the interrupt.

15

20

### Enumeration and Error Record (EER)

The EER is used by the USB host system 200 to notify the Main Processor 310 the connect and disconnect of USB devices 320, the enumeration status of devices, and system errors. It has the following format.

25

EnumErr: [wStatus, bDeviceAddress, idVendor, idProduct, bcdDevice, bConfiguration, Reserved]

30

The format of the EER in the DCM 220 is as shown in Figure 9 for one embodiment of this invention. Other information in the device descriptors, such as device class, subclass, number of interfaces and configurations etc., may also be passed to the Main Processor 310. To avoid conflict with the Main Processor 310, a special segment 410 of the DCM 220 is reserved for the USB host system 200 to send EER 900 to the Main Processor 310.

When a device 320 is connected, the USB host system 200 automatically detects it, and sends interrupt to the Main Processor 310. When a device 320 is disconnected, the USB host system 200 also notifies the Main Processor 310 with an interrupt request. Upon receiving the interrupt, the Main Processor 310 reads the EER 900 address from 430 and 435 in the DCM 220. Reading 435 clears the interrupt. The address of EER 900 is in the Last Address range of the DCM 220 which identifies itself to the Application Processor 310 as an EER 900. An EER 900 uses special bit patterns to identify the Record as an enumeration report record or an system error report record.

After reading the EER 900, the Main Processor 310 should write the starting address of the EER 900 to 420 and 425 in the DCM 220 to notify the USB host system 200 that the EER 900 has been read, so that the USB host system 200 may send the next ENR, if there is one.

#### Summary of the USBDI

The four types of Records described above provide the following services and mechanisms to the Client 150:

- Configuration and control of devices via control pipe (using CPR 500)
- Transfer services via both control and data pipe mechanisms with all four types of pipes (using CPR 500 and DPR 600)
- Event notification (using EER 900)

- Status reporting and error recovery (reporting using bStatus and wXferCount, recovery done automatically transparent to the Main Processor 310)
  - System/Device/Pipe abort/reset/suspend/resume (using SCR 800)
  - Pipe halt and clear pipe halt (using SCR 800)
- 5      • Queuing and dispatching I/O request packets (IRPs) (done automatically transparent to Main Processor 310)

10      The Main Processor 310 has the flexibility in allocating the starting address and size of the buffers for the CPR 500 and DPR 600, and in establishing multiple DPRs 600 to fit the need of the different USB transfers. For example, multiple DPR 600 may be set up for a single isochronous pipe to ensure data rate.

15      The Main Processor 310 should not use the same area to initiate a different Record before the previous Record is done because the starting address of the Records is used to identify the Records.

20      Although the foregoing description of the preferred embodiment of the present invention has shown, described, and pointed out the fundamental novel features of the invention, it will be understood that various omissions, substitutions, and changes in the form of the detail of the programs, processes, systems and methods as illustrated, as well as the uses thereof, may be made by those skilled in the art without departing from the spirit of the present invention. Hence, the scope of the present invention should not be limited to the foregoing discussion, but should be defined by the appended claims.

## Claims

### WHAT IS CLAIMED IS:

1. A USB host system comprising:
  - a first processor implementing a function of a USB driver;
  - 5 a downstream USB port; and
  - a communication area accessible both by a second processor and by the first processor.
2. The USB host system in Claim 1 where the communication area is a dual port memory.
- 10 3. The USB host system in Claim 1 where the communication area consists of multiple FIFO registers.
4. The USB host system in Claim 1 where an interrupt polled from a USB interrupt pipe is converted to an interrupt signal to the Main Processor.
5. The USB host system in Claim 1 where the said second processor interfaces  
15 the host system via a standard microprocessor bus.
6. The USB host system in Claim 1 where a hub is used to provide multiple downstream USB ports.
7. The USB host system in Claim 1 where data in the communication area are directly sent out on the USB bus.
- 20 8. The USB host system in Claim 1 where data received from the USB bus are written directly in the communication area.
9. The USB host system in Claim 1 where the said host system is used to provide a USB host function to the said second processor.
10. The USB host system in Claim 1 where the said host system is used to provide  
25 a USB host function to the said second processor which runs an operating system supporting USB, by intercepting calls to the USBBD in the said operating system.
11. A USB host system comprising:
  - a first processor implementing a function managing a USB host controller;
  - 30 a downstream USB port; and

an interface that provides a high-level USB pipe view of a USB system to a program running on a second processor.

12. The USB host system in Claim 11 where the said interface uses a memory that can be accessed by both the first processor and the second processor.
- 5 13. The USB host system in Claim 11 where the second processor interfaces the host system via a standard microprocessor bus.
14. The USB host system in Claim 11 where a hub is used to provide multiple downstream USB ports.
15. The USB host system in Claim 11 where the said host system is used to provide a USB host function to the said second processor.
- 10 16. The USB host system in Claim 1 where the said host system is used to provide a USB host function to the said second processor which runs an operating system supporting a USB, and USB transfer request by the said second processor intercepting calls to the USB in the said operating system.
- 15 17. An information processing system comprising:
  - a first processor; and
  - a data transfer host system comprising a second processor implementing a first data transfer driver managing a data transfer between the said first processor and a device; a data transfer port for connecting a device to the said data transfer host system; and an interface with the first processor that provides a high-level view of the data transfer process to the first processor.
- 20 18. The information processing system in Claim 17 where the said interface uses a memory area that can be accessed by both the said first processor and the said second processor.
- 25 19. The information processing system in Claim 17 where the said second processor is used to reduce the number of interrupts to the said first processor.
20. The information processing system in Claim 17 where the said second processor is used to reduce the frequency of interrupts to the said first processor.
- 30

21. The information processing system in Claim 17 where the said first processor interfaces the data transfer host system via a standard microprocessor bus.
22. The information processing system in Claim 17 where a hub is used to provide multiple ports for connecting a plural of devices.
- 5 23. The information processing system in Claim 17 where the said first processor contains a second data transfer driver capable of managing the same said data transfer and a data transfer request by the said first processor to the said second data transfer driver is carried out by the said data transfer host system.
24. A USB host comprising:
- 10 a first processor implementing a function of a USB system;  
a downstream USB port; and  
a memory accessible by both the said first processor and an second processor external to the said USB host, whereby a first area of the memory with a first predetermined format is used for a first type of transfer, and a second area of the memory with a second predetermined format is used for a second type of transfer.
- 15 25. The USB host in Claim 24 where a hub is connected to the downstream USB port so that multiple devices can be connected to the system.
26. The USB host in Claim 24 where the memory is connected to both the first processor and the second processor via a standard microprocessor bus interface.
- 20 27. The USB host in Claim 24 where a third area of the memory with a third predetermined format is used for reporting device connection, enumeration and removal to the second processor.
- 25 28. The third area of the storage device in Claim 27 where the said third area is in a part of the said memory which is read-only to the second processor.
29. The USB host in Claim 24 where a fourth area of the memory with a fourth predetermined format is used for sending a USB command to the said USB host.
- 30 30. The USB host in Claim 24 where the starting address of each memory area for

- a transfer is used to identify the transfer.
31. The USB host in Claim 24 where the second processor allocates the size of a memory area for a transfer to fit the need of the transfer.
32. The USB host in Claim 24 where the second processor allocates the number of the said areas to fit the need of a transfer.
33. The USB host in Claim 24 where the starting address of the said first area can be in different part of the memory.
34. The USB host in Claim 24 where the starting address of the said second area can be in different part of the memory.
35. The USB host in Claim 24 where the starting address of the said first and second area are in the same location of the memory.
36. The USB host in Claim 24 where the said predetermined formats of the said first and second areas are the same.
37. The USB host in Claim 24 where the starting address of the said first and second areas are stored at fixed locations of the memory.
38. The USB host in Claim 24 where the said second processor writes a transfer request in a said area in the memory and notifies the first processor with an interrupt signal.
39. The USB host in Claim 24 where the first processor writes the status or data of a transfer into a said area in the memory and notifies the said second processor with an interrupt signal.
40. The USB host in Claim 24 where a single format of the said second area implements isochronous, interrupt and bulk transfers.
41. A USB host comprising:
- a first processor implementing a function of a USB system;
  - a downstream USB port; and
  - a memory accessible by both the said first processor and a second processor external to the said USB host, whereby the said second processor initiates a USB transfer by writing a transfer request, and data for the said transfer, if there is any, into a first area in the said memory,

and the said first processor carries out the transfer, and writes the status of the said transfer, and data from the said transfer, if there is any, into a second area in the said memory.

- 5
42. The USB host in Claim 41 where a hub is connected to the downstream USB port so that multiple devices can be connected to the system.
43. The USB host in Claim 41 where the memory is connected to both the first processor and the second processor via a standard microprocessor bus interface.
- 10
44. The USB host in Claim 41 where the said first area in the said memory and the said second area in the said memory are the same area.
45. The USB host in Claim 41 where the said first area in the said memory and the said second area in the said memory use a same predefined format.
- 15
46. The USB host in Claim 41 where the said second processor runs an operating system that supports USB and a USB transfer request by the said second processor to a USB on the second processor is carried out by the said USB host.
- 20
47. The USB host in Claim 41 where when the said first processor carries out the transfer, and writes the status of the said transfer, and data from the said transfer, if there is any, into a second area in the said memory, the said USB host generates an interrupt signal to the said second processor to notify the said second processor.
- 25
48. The USB host in Claim 41 where when the said second processor initiates a USB transfer by writing a transfer request, and data for the said transfer, if there is any, into a first area in the said memory, the said second processor generates an interrupt signal to the said USB host to notify the said USB host.



### Abstract of the Disclosure

This invention is a USB host comprising a first processor implementing a function of a USB system and presenting a high-level pipe view of USB to a second processor. In one embodiment of this invention, first processor and the second processor communicate through a data communication memory (DCM) which can be accessed by both the first processor and the second processor, using a plural of predefined transfer record formats. From the second processor's point of view, a USB transfer becomes reading from and writing to the DCM with predefined record formats which can be done by filling templates.

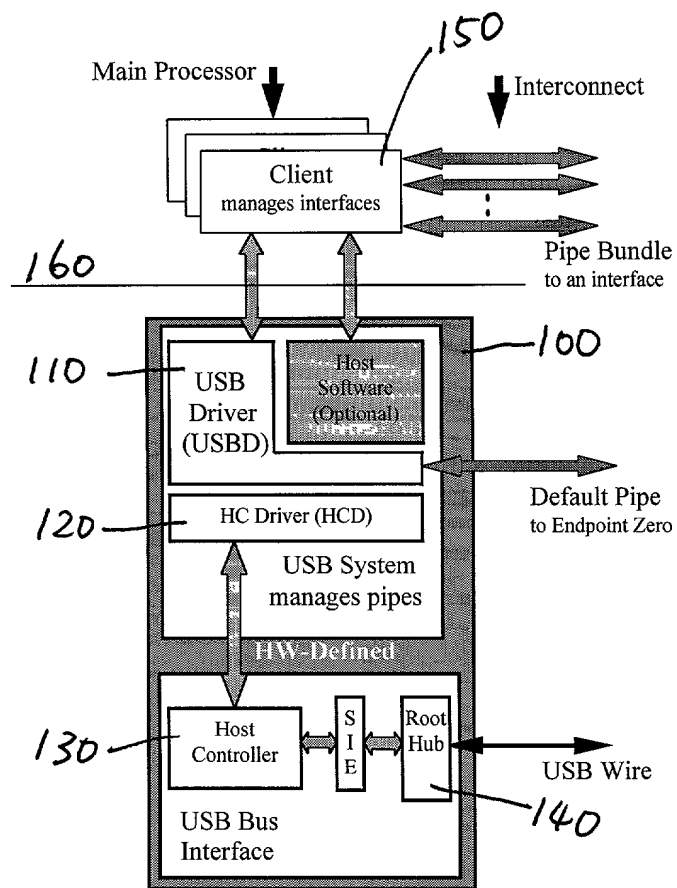


Figure 1

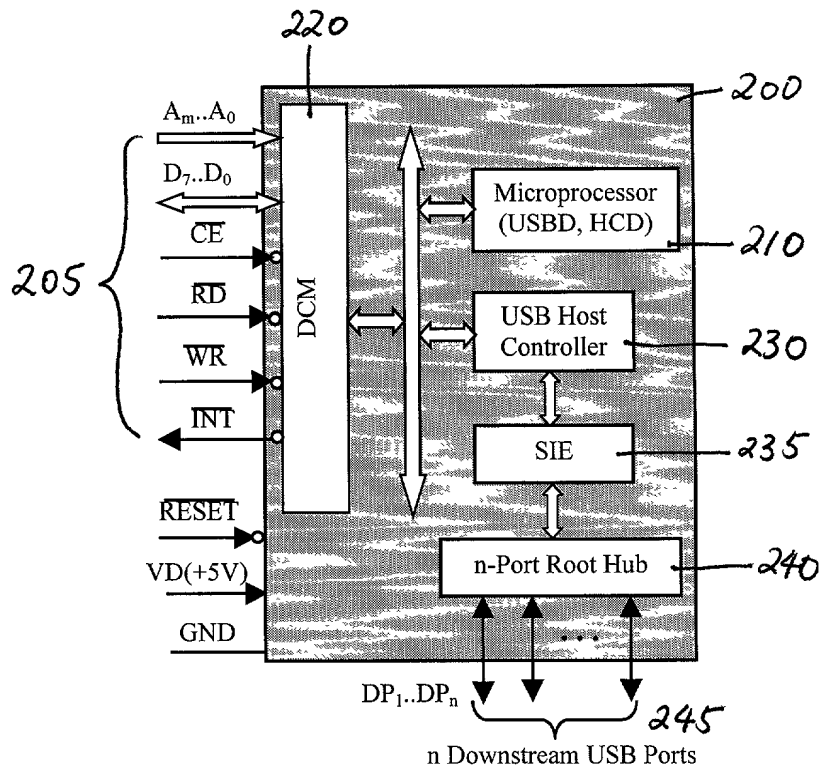


Figure 2

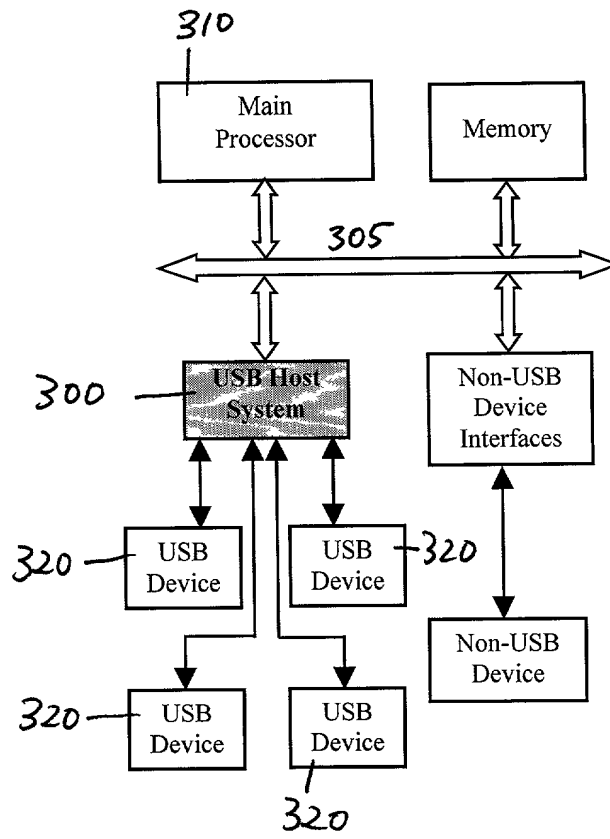


Figure 3

|                |                                                                                                                                                                                                                                                  |     |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 000H           | Area used for CPR, DPR, and SCR. The Main Processor 310 has the flexibility in allocating buffer sizes and multiple Records to fit the need of different USB transfers.<br><br>Main Processor 310: Read/Write<br>USB Host System 200: Read/Write | 400 |
| Last Address-m | Reserved for EER<br><br>USB Host System 200: Write only<br>Main Processor 310: Read only                                                                                                                                                         | 410 |
| Last Address-3 | MTUH: Main Processor 310 to USB host system 200 Message High Byte. Main Processor 310: Write only. USB host system 200: Read only                                                                                                                | 420 |
| Last Address-2 | UTMH: USB Host System 200 to Main Processor 300 Message High Byte. Main Processor 310: Read only. USB Host System 200: Write only                                                                                                                | 430 |
| Last Address-1 | UTML: USB Host System 200 to Main Processor 310 Message Low Byte. Main Processor: Read only. USB Host System 200: Write only<br>Writing to UTML sends an interrupt to Main Processor 310                                                         | 435 |
| Last Address   | MTUL: Main Processor 310 to USB host system 200 Message Low Byte. Main Processor 310: Write only. USB Host System 200: Read only<br>Writing to MTUL sends an interrupt to USB Host System 200                                                    | 425 |

Figure 4

| Field           | Size | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| bmControl       | 1    | Used by the Main Processor 310 to identify types of I/O request packet (IRP), and to control USB host system 200 activities. For Control Pipe Record: Bit 7 is 0, Bit 6 is 1, Bits 5...0 are Reserved.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| bStatus         | 1    | Used by the USB host system 200 to report the status of the IRP to the Main Processor 310.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| wXferCount      | 2    | For transfer from host to device: Used by the USB host system 200 to report to the Main Processor 310 the number of bytes successfully sent to the device. It must be less than wLength.<br>For transfer from device to host: Used by the USB host system 200 to report to the Main Processor 310 the number of bytes of data received and put in the Data area. It must be less than wLength.                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| bDeviceAddress  | 1    | USB Device address, bit 7 always zero                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| bEndpointNumber | 1    | Endpoint number, default is endpoint 0. Bits 7-5 always zero                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| bRequestType    | 1    | Type of command for the USB device.<br>Bit 7: Data transfer direction<br>0 = Host-to-device, 1 = Device-to-host<br>Bits 6...5: Type<br>0 = Standard request (Defined in Chapter 9 of USB Specification)<br>1 = Class request (Defined in USB Device Class Specification)<br>2 = Vendor request (Also called Client Request, used by the Client Software to control a USB device. Defined by a developer writing the device driver)<br>3 = Reserved<br>Bits 4...0: Recipient<br>0 = A downstream Device, 1 = An Interface in a device<br>2 = An Endpoint in a device, 3 = Other, 4...31 = Reserved<br>All the standard requests are handled by the USB host system 200. In normal operation, the user only needs to use the class and vendor requests. Thus, in normal operation, bits 6...5 of bRequestType should be 01 or 10. |
| bRequest        | 1    | This field specifies the particular command for the USB device. Defined by USB specification if bits 6...5=00 in bmRequestType (Chapter 9 of USB Specification). Defined by USB device driver if bits 6...5=10 in bmRequestType                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| wValue          | 2    | The contents of this field vary according to the request. It is used to pass a parameter to the device, specific to the request. Defined by USB device driver if it is a client request.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| wIndex          | 2    | The contents of this field vary according to the request. It is used to pass a parameter to the device, specific to the request. Defined by USB device driver if it is a client request.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| wLength         | 2    | For transfer from host to device: Number of bytes of data to transfer<br>For transfer from device to host: Size of data buffer in bytes<br>If this field is zero, there is no data phase for the control transfer.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Data            | vary | For transfer from host to device: Actual data if data is to be sent to device via the control pipe. Number of bytes of data specified wLength.<br>For transfer from device to host: Buffer area                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

Figure 5

| Field           | Size | Description                                                                                                                                                                                                                                                                                                                                                                                    |
|-----------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| bmControl       | 1    | Used by the Main Processor 310 to identify types of IRP, and to control USB host system 200 activities. For Data Pipe Record:<br>Bit 7: 0<br>Bit 6: 0<br>Bits 5...0: Reserved.                                                                                                                                                                                                                 |
| bStatus         | 1    | Used by the USB host system 200 to report the status of the IRP to the Main Processor 310.                                                                                                                                                                                                                                                                                                     |
| wXferCount      | 2    | For transfer from host to device: Used by the USB host system 200 to report to the Main Processor 310 the number of bytes successfully sent to the device. It must be less than wLength.<br>For transfer from device to host: Used by the USB host system 200 to report to the Main Processor 310 the number of bytes of data received and put in the Data area. It must be less than wLength. |
| bDeviceAddress  | 1    | USB Device address, bit 7 always zero                                                                                                                                                                                                                                                                                                                                                          |
| bEndpointNumber | 1    | Endpoint number, default is endpoint 0. Bits 7-5 always zero                                                                                                                                                                                                                                                                                                                                   |
| wLength         | 2    | For transfer from host to device: Number of bytes of data to transfer<br>For transfer from device to host: Size of data buffer in bytes                                                                                                                                                                                                                                                        |
| Data            | vary | For transfer from host to device: Actual data if data is to be sent to device via the control pipe. Number of bytes of data specified wLength.<br>For transfer from device to host: Buffer area                                                                                                                                                                                                |

Figure 6

| Command Name     | Description                                                                                                                                                                                                                                                                                            |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| USB System Reset | Resets USB host system 200 and all downstream hubs and devices. All Records will be lost and all devices will be re-enumerated.                                                                                                                                                                        |
| Global Suspend   | Suspend all hubs and devices including the root hub. However, the USB host system 200 will not be suspended. The USB host system 200 does not support remote wakeup. After a System Suspend, the system can only be waken up by the Main Processor issuing a System Resume to the USB host system 200. |
| Global Resume    | Resumes all hubs and devices in the system.                                                                                                                                                                                                                                                            |
| Device Reset     | Sending a USB Reset signal to the designated device.                                                                                                                                                                                                                                                   |
| Device Suspend   | Suspend a designated device.                                                                                                                                                                                                                                                                           |
| Device Resume    | Resume a designated device.                                                                                                                                                                                                                                                                            |
| Pipe Reset       | The pipe's IRPs are aborted. The host state is moved to Active. If the reflected endpoint state needs to be changed, that must be commanded explicitly by the USB client.                                                                                                                              |
| Pipe Halt        | The pipe's state is set to Halted.                                                                                                                                                                                                                                                                     |
| Clear Pipe Halt  | The pipe's state is cleared from Halted to Active.                                                                                                                                                                                                                                                     |
| Pipe Abort       | All of the IRPs scheduled for a pipe are retired immediately and returned to the client with a status indicating they have been aborted. Neither the host state nor the reflected endpoint state of the pipe is affected.                                                                              |

Figure 7




| Field           | Size | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| bmControl       | 1    | Used by the Main Processor 310 to identify types of IRP, and to control USB host system 200 activities. For System Command Record:<br>Bit 7: 1<br>Bits 6...5: Reserved<br>Bits 4...3: Command Category<br>00: Command applies to USB system<br>01: Command applies to a Device<br>10: Command applies to an Endpoint<br>11: Reserved<br>Bit 2: Reserved<br>Bits 1...0: Command Name<br>For USB system and Device (Bits 4...3=00 or 01)<br>00: System or Device Reset<br>01: System or Device Suspend<br>10: System or Device Resume<br>11: Reserved<br>For Endpoint (Bits 4...3=10)<br>00: Pipe Reset<br>01: Pipe Halt<br>10: Clear Pipe Halt<br>11: Pipe Abort |
| bStatus         | 1    | Used by the USB host system 200 to report the status of the SCR to the Main Processor.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| bDeviceAddress  | 1    | USB Device address, bit 7 always zero. Not used if Bits 4...3 of bmControl=00.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| bEndpointNumber | 1    | Endpoint number. Bits 7-5 always zero.<br>Not used if Bits 4...3 of bmControl=00 or 01.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

Figure 8

| Field          | Size | Description                                                                                                                                                                                                                                                        |
|----------------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| bStatus        | 1    | Used by the USB host system 200 to report the status of the device and systems errors to the Main Processor.<br>Bit 7=0: Device enumeration report.<br>Bit 7=1: System error report. The Record consists of only four bytes.<br>Bits 6...0: Pending, being tested. |
| bDeviceAddress | 1    | When bStatus_Bit_7=0, this field is the address assigned to the USB Device by the USB host system 200, bit 7 always zero.<br>When bStatus_Bit_7=1, this field is an auxiliary system error code.                                                                   |
| idVendor       | 2    | When bStatus_Bit_7=0, this field is the Vendor ID (assigned by the USB).<br>When bStatus_Bit_7=1, this field is reserved.                                                                                                                                          |
| idProduct      | 2    | Product ID. Not present when bStatus_Bit_7=1                                                                                                                                                                                                                       |
| bcdDevice      | 2    | Device release number in BCD. Not present when bStatus_Bit_7=1.                                                                                                                                                                                                    |
| bConfiguration | 1    | The current configuration number of the device. Upon enumeration, the device is configured to its first configuration specified by the device descriptors. Not present when bStatus_Bit_7=1.                                                                       |
| Reserved       | 3    | Not present when bStatus_Bit_7=1.                                                                                                                                                                                                                                  |

Figure 9

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|                                                                                                                                                                                                                                                                                             | <b>First Named Inventor</b>   | Jing Wang |
|                                                                                                                                                                                                                                                                                             | <b>COMPLETE IF KNOWN</b>      |           |
|                                                                                                                                                                                                                                                                                             | <b>Application Number</b>     | /         |
|                                                                                                                                                                                                                                                                                             | <b>Filing Date</b>            | 1/24/2000 |
|                                                                                                                                                                                                                                                                                             | <b>Group Art Unit</b>         |           |
|                                                                                                                                                                                                                                                                                             | <b>Examiner Name</b>          |           |

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

USB Host System

the specification of which (Title of the Invention)

☒ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) as United States Application Number or PCT International Application Number and was amended on (MM/DD/YYYY) (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

| Prior Foreign Application Number(s) | Country | Foreign Filing Date (MM/DD/YYYY) | Priority Not Claimed     | Certified Copy Attached? |                          |
|-------------------------------------|---------|----------------------------------|--------------------------|--------------------------|--------------------------|
|                                     |         |                                  |                          | YES                      | NO                       |
|                                     |         |                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
|                                     |         |                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
|                                     |         |                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
|                                     |         |                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

| Application Number(s) | Filing Date (MM/DD/YYYY) | <input type="checkbox"/> Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto. |
|-----------------------|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| 60/117,313            | 01/26/1999               |                                                                                                                                                  |

[Page 1 of 2]

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|---------|------------------------------------------|-----------|--------------|-----|--------------|
| Name    | Ping Liang                               |           |              |     |              |
| Address | TransDimension International Corporation |           |              |     |              |
| Address | 3637 Canyon Crest Drive J100             |           |              |     |              |
| City    | Riverside                                | State     | CA           | ZIP | 92507        |
| Country | USA                                      | Telephone | 909-683-3600 | Fax | 909-683-3861 |

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

|                                        |                   |                                                                               |    |         |         |
|----------------------------------------|-------------------|-------------------------------------------------------------------------------|----|---------|---------|
| Name of Sole or First Inventor:        |                   | <input type="checkbox"/> A petition has been filed for this unsigned inventor |    |         |         |
| Given Name (first and middle [if any]) |                   | Family Name or Surname                                                        |    |         |         |
| Jing                                   |                   | Wang                                                                          |    |         |         |
| Inventor's Signature                   |                   |                                                                               |    | Date    | 1/24/00 |
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| Post Office Address                    | 158 Clearwood Ave |                                                                               |    |         |         |
| Post Office Address                    |                   |                                                                               |    |         |         |
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|                                        |                   |                                                                               |    | Country | USA     |

☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

Please type a plus sign (+) inside this box → **+**

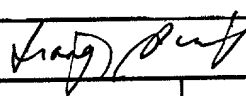

PTO/SB/02A (3-97)

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**DECLARATION****ADDITIONAL INVENTOR(S)**  
Supplemental Sheet  
Page 1 of 1

|                                            |                                                                                     |                                                                               |    |                        |       |             |           |
|--------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|----|------------------------|-------|-------------|-----------|
| Name of Additional Joint Inventor, if any: |                                                                                     | <input type="checkbox"/> A petition has been filed for this unsigned inventor |    |                        |       |             |           |
| Given Name (first and middle (if any))     |                                                                                     |                                                                               |    | Family Name or Surname |       |             |           |
| Ping                                       |                                                                                     |                                                                               |    | Liang                  |       |             |           |
| Inventor's Signature                       |    |                                                                               |    |                        |       | Date        | 1/24/2000 |
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| City                                       | Riverside                                                                           | State                                                                         | CA | ZIP                    | 92508 | Country     | USA       |
| Name of Additional Joint Inventor, if any: |                                                                                     | <input type="checkbox"/> A petition has been filed for this unsigned inventor |    |                        |       |             |           |
| Given Name (first and middle (if any))     |                                                                                     |                                                                               |    | Family Name or Surname |       |             |           |
| Xiaogang                                   |                                                                                     |                                                                               |    | Luo                    |       |             |           |
| Inventor's Signature                       |  |                                                                               |    |                        |       | Date        | 1/24/2000 |
| Residence: City                            | Montevideo                                                                          | State                                                                         | MN | Country                | USA   | Citizenship | China     |
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| City                                       | Montevideo                                                                          | State                                                                         | MN | ZIP                    | 56265 | Country     | USA       |
| Name of Additional Joint Inventor, if any: |                                                                                     | <input type="checkbox"/> A petition has been filed for this unsigned inventor |    |                        |       |             |           |
| Given Name (first and middle (if any))     |                                                                                     |                                                                               |    | Family Name or Surname |       |             |           |
|                                            |                                                                                     |                                                                               |    |                        |       |             |           |
| Inventor's Signature                       |                                                                                     |                                                                               |    |                        |       | Date        |           |
| Residence: City                            |                                                                                     | State                                                                         |    | Country                |       | Citizenship |           |
| Post Office Address                        |                                                                                     |                                                                               |    |                        |       |             |           |
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